CHAPTER 6

Electric Energy

Getting Ready...

- What energy conversions take place inside an electric appliance?
- Explain how, with electric appliances, input energy is always greater than useful output energy.
- Why is it important to conserve electric energy?
- How can you reduce the monthly electric bill in your home?

Science Log

Describe how your family could prepare for power outages. How would the plan change if you expected the power to be off for several days in winter? Describe a winter survival kit for your home.

High winds, lightning, sleet on power lines, and heavy snow are the main causes of electric power failures. In recent years, the worst instance happened when an ice storm struck Ontario, Québec, and New Brunswick. Two million people were left for days — some for weeks — without electricity.

Dairy farmers were hit hard. Without electricity, feeders and milking machines were useless. Cattle got sick and many farmers had to shoot most of their herd. Dead cows that should have been used for meat were stacked outside. With no electricity, meat packers were closed too.

Many people wondered if power would come back on before their houses suffered major damage from frozen water pipes that burst and spilled water over floors or through ceilings.

Power outages — both the long ones and those that last only an hour — show how much we rely on electricity. Without power, can you cook your food or heat your house? How can you keep water pipes from freezing?

In this chapter you will study technologies that generate electric power. You will investigate energy conversions in electric appliances, calculate rates of energy transfer, and evaluate the efficiency of electric energy conversion systems.

at Home

What You Will Learn

In this chapter you will learn:

- about the technologies that convert other forms of energy into electric energy
- how appliances convert electric energy into other types of energy efficiently
- how to calculate the efficiency of electric devices
- how to measure electric energy and electric power
- why it is important to conserve electric energy

Why It Is Important

- Can you imagine life without light bulbs, television, CD players, and video games? You use electric energy every day, not only for fun but for the basics like light and heat. The way we use electricity has changed the way we live. It is hard to imagine life without it.

Skills You Will Use

In this chapter you will:

- identify technologies used to generate electricity
- investigate light intensity and how solar cells produce energy
- design a model that converts the energy of flowing water into electric energy
- calculate the amount of electric power used by electric appliances
- calculate the efficiency of electric appliances

Starting Point ACTIVITY

Where Does Electricity Come From?

Although electricity has always been around us in nature, it was only 200 years ago that people discovered how to *make* electricity. Discover for yourself how electricity is made.

What You Need

sandpaper

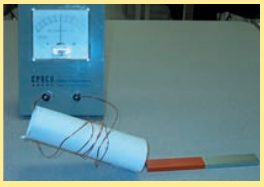
1.5 m thin, bare copper wire

toilet paper tube

electrical tape

galvanometer

bar magnet



What to Do

1. Use sandpaper to polish 2 cm at each end of the wire.
2. Wrap 20 coils of wire around the tube. Tape the wire in place on the tube and attach an end of the wire to each terminal of the galvanometer.
3. Move the magnet into and out of the paper tube.
4. Observe the galvanometer. Record the effect of moving the magnet.

What Did You Discover?

1. What sign is there that something in the system has changed?
2. Which way does the needle move when the North pole goes into the tube?
3. Identify the input energy, the converter, and the output energy in this system.
4. Discuss how you might increase the amount of electric energy generated in this system. Record your group's ideas.

6.1 Generating Electric Energy

Figure 6.1 Michael Faraday, the son of a blacksmith, received little formal education. While apprenticed to a bookbinder in London, he read books on scientific subjects and experimented with electricity. In 1812, he made notes as he listened to British chemist Sir Humphry Davy. He sent these notes to Davy and asked for a job. Davy hired Faraday as a laboratory assistant. Today, Faraday is probably better known than Davy.

In Alberta, the energy you use to light your room at night probably came from the potential energy in a lump of coal. Energy from burning coal turns a generator, which in turn produces electricity. In this way, the potential energy in coal is converted to electric energy.

In the early 1800s, Michael Faraday investigated the magnetic field around magnets. He found that pushing a magnet through a coil of wire generated an electric current. Adding more coils or using stronger magnets produced more electric energy. Using these observations, he made the first electric **generator**. A generator is a device that makes electricity.

Use the Find Out activity to help you ask and answer some of the questions Faraday must have had.

Find Out ACTIVITY

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Generating Electric Energy

In this activity, you will build a generator. You will also have an opportunity to evaluate your discussion at the end of the Starting Point activity on page 99.

What You Need

toilet paper tube
sandpaper
electrical tape
bar magnet
galvanometer
5 m thin bare, copper wire

What to Do

1. Work with a partner to construct the same set-up you used in the Starting Point activity on page 99.
2. Move a magnet into and out of the tube. Note and record the effect on the galvanometer.
3. Repeat Step 2, moving the magnet at different speeds.
4. Repeat Steps 2 and 3. This time, hold the magnet still and move the tube back and forth, so it covers and then uncovers the magnet. Record your observations.
5. Wrap 20 more coils of wire around the paper roll. Secure the wire with tape. Repeat Steps 2 to 4.
6. Wrap 20 more coils of wire around the paper roll. Repeat Steps 2 to 4.

What Did You Find Out?

1. What happens to the galvanometer needle when the number of turns of wire is increased?
2. Does it make any difference whether it is the magnet or the coil of wire that moves?
3. You have found how electric energy can be produced by moving a magnet through a coil of wire. Explain how you can increase the amount of electric energy generated in a system.

Figure 6.2 As a teenager, Canadian inventor Thomas "Carbide" Willson experimented with electric generators, which are sometimes called *dynamos*. He and a blacksmith built one of Canada's earliest generators that gave Hamilton, Ontario its first electric light.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

Willson went on to make other discoveries, including an inexpensive way to make acetylene. To find out more about this interesting Canadian, go to the above web site. Then go to Internet Connects, Unit B, Chapter 6, and then to Carbide Willson.

Generating Electricity

A generator is one device that produces electricity. As you discovered in the Find Out activity, the two main parts of a generator are a magnet and a coil of wire. Moving a wire coil through a magnetic field produces electricity. This works when either the magnet or the wire coil move.

Making the huge amounts of electricity we need today involves gigantic generators. In the next sections, you will look at the energy conversions used to turn these generators cheaply.

READING Check

How does a generator produce electricity?

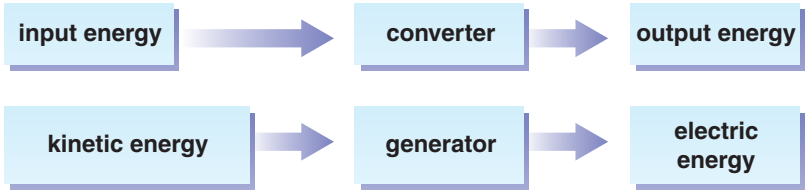


Figure 6.3 Energy conversion in a generator

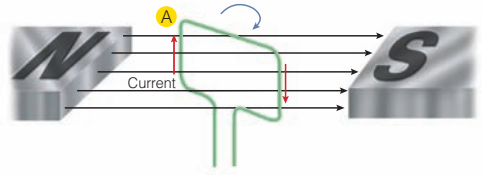


Figure 6.4 A generator consists of a magnet and a coil of wire. Spinning the coil of wire through the magnetic field is one way to generate electricity.

Try This!

Small electric motors used in model cars, trains, and airplanes can be used as generators. Connect both terminals of a small motor with a short, thin wire. Connect the wire to a galvanometer. Spin the motor. What happens to the needle of the galvanometer?

Check Your Understanding

1. Draw and label the main parts of a generator.
2. Describe how a simple generator produces electric energy.
3. List two things you can do to increase the amount of electric energy produced by a generator.

Key Terms

generator

6.2 Generating and Distributing Electric Energy

READING Check

List three ways electricity is generated in Canada.

Most electricity is made in a generator. Generators contain one or more turbines. You made a turbine during Design & Do 5–D: Input and Output Energy.

In order to make electricity, turbines need to be connected to a generator. As the blades of the turbine turn, their kinetic energy is transformed into kinetic energy in the generator. This is what produces electric energy.

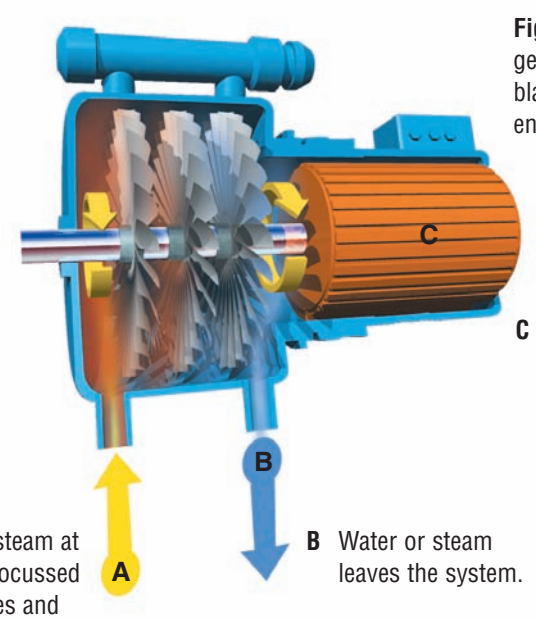


Figure 6.5 Almost all electricity is made in a **turbine**–generator combination like this. Turbines have sets of blades adjusted to the correct angle to collect the most energy from fast-moving water, steam, or wind.

A Moving water or steam at high pressure is focussed onto turbine blades and turns the machine.

B Water or steam leaves the system.

C The turbine is attached to the generator. As the turbine turns, the kinetic energy of the spinning turbine is transformed into kinetic energy in the generator which, in turn, produces electric energy.

Figure 6.6A Hydro-electric plants convert the kinetic energy of moving water (such as water falling over a dam or waterfall) into electric energy.

Figure 6.6B Thermo-electric power plants convert chemical energy stored in fossil fuel. This energy is converted to thermal energy, then to kinetic energy, then to electric energy.

Figure 6.6C Thermonuclear plants split atoms, releasing thermal energy that is converted to kinetic energy, then to electric energy.

Generating Electric Energy in Canada

Think About It

Why does it make sense to make electricity using moving water in one place and using thermal energy in another?

What to Do

1. Review the data in Table A.

Table A Sources for Electric Energy Production in Canada by Percentage

	Type of Power Plant					
	Hydro-electric	Thermonuclear	Fossil Fuel Thermo-electric			Other
			Coal	Natural Gas	Oil	
percentage of electricity produced	63	17	15	2	2	1

2. Use the data to make a bar graph.
   - Place the type of power plant on the horizontal axis (*x*-axis).
   - Place the percentage on the vertical axis (*y*-axis).
   - Use the vertical axis for percentage of electricity produced.

Computer CONNECT

Use a computer spreadsheet program to generate and print out the bar graph.

Analyze

1. Compare the amount of electricity produced in Canada by hydro-electric plants and thermonuclear plants.
2. Compare the amount of electricity produced by the three fossil fuel sources.
3. Coal is considered by many to be a dirty, environmentally unfriendly fuel to burn. Why do you think natural gas is used less often than coal?
4. In Alberta, 82 percent of the electricity produced is generated by burning coal. Only four percent is produced by hydro-electric sources. Why do you think Alberta generates so little electricity with hydro-electric stations?

Off the Wall

How much solar energy falls on Earth's surface each minute?

Picture 15 trains. Each train is 7184 km long and stretches from Victoria, British Columbia to St John's, Newfoundland. The 15 trains are side by side, full of coal, and each stretched across Canada. The amount of potential energy stored in the coal is how much energy we get from the Sun each minute!

Figure 6.7

Coal-fired Thermo-electric Generation

Coal-fired thermo-electric plants use the fuel that is cheap and plentiful in Alberta.

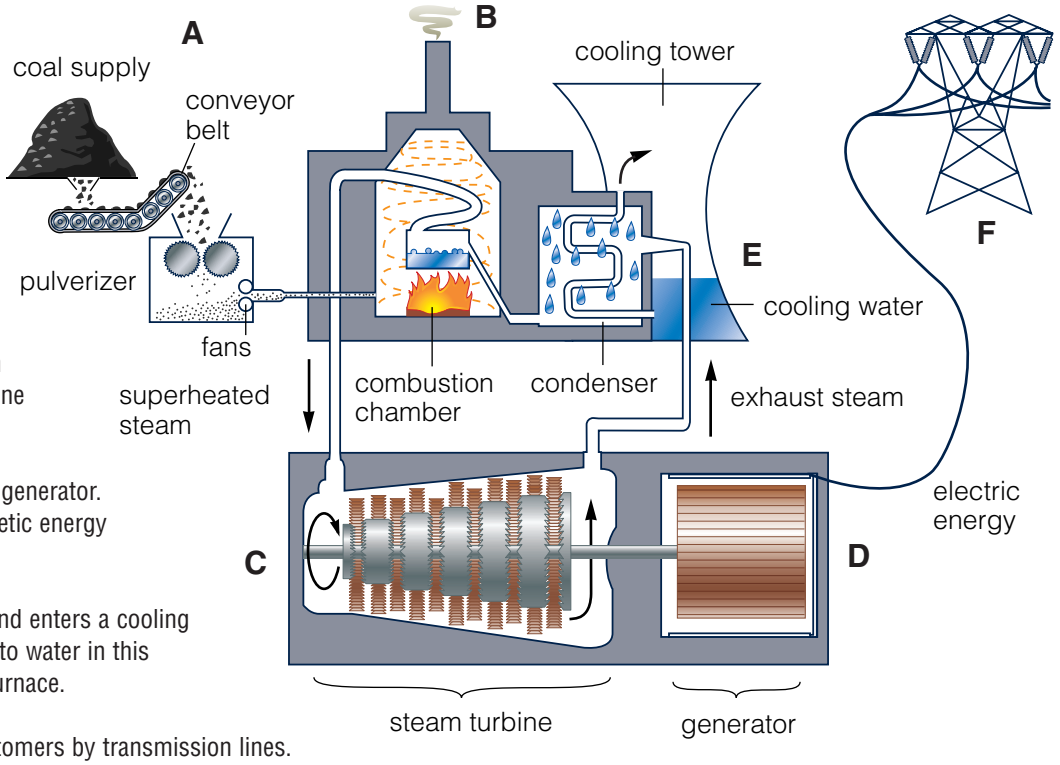
In modern thermal plants, smoke from the burning coal is put through *scrubbers*. These scrubbers remove some of the harmful chemicals from the smoke before it is released to the air.

Study Figure 6.8 to see how coal-fired thermo-electric plants work. Natural gas is used in a similar way. Read Table 6.1 and consider the advantages and disadvantages of using fossil fuels like coal, petroleum, and natural gas to make electricity.

READING Check

Describe how coal is used to produce electricity.

Figure 6.8 In Alberta, coal is the most common fuel used to generate electric energy.



A Lumps of coal are broken down to a powder. This pulverized coal is blown into the combustion chamber of the furnace. Pulverized coal burns rapidly and efficiently.

B In the furnace, thermal energy from burning coal converts water to steam.

C High-pressure steam flows through pipes and onto the fan blades of the turbine. The turbine spins with kinetic energy.

D The spinning turbine turns the generator. The generator converts the kinetic energy into electric energy.

E The steam leaves the turbine and enters a cooling chamber. Steam is condensed to water in this chamber and returned to the furnace.

F Electricity is distributed to customers by transmission lines.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

To learn more about the role of coal-burning generating stations in Alberta, go to the above web site. Then go to Internet Connects, Unit B, Chapter 6, and then to Generating Electricity with Coal.

Table 6.1 Advantages and Disadvantages of Using Fossil Fuels

Advantages	Disadvantages
• Relatively inexpensive to use. • Alberta and other regions of Canada are well-supplied.	• Combustion of fossil fuels produces carbon dioxide, which can cause global climate change. • Combustion of fossil fuels may also produce sulfur dioxide, which can result in acid precipitation. • Supplies of fossil fuels are limited and cannot be renewed. • Mining and processing operations damage the environment.

Electric Energy from Water

Hydro-electric power plants produce much of the electric energy in Canada. This type of generation system uses the kinetic energy from falling water to generate electricity. Large dams are built high above the generating station.

Hydro-electric power is a clean and efficient way to generate electric energy. Once the facilities are built and working, there is little environmental damage. No harmful emissions are released into the atmosphere. Generators run with little maintenance.

The main disadvantage of hydro-electric power is that the generating stations require large dams. These dams produce large lakes or reservoirs that flood land and change the ecology of an area.

READING Check

List two advantages and one disadvantage to generating electric energy using the power in moving water.

DESIGN & DO

INVESTIGATION 6–B

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting

Communication and Teamwork

Making Hydro-electric Energy

Challenge

Design and construct a device that converts the kinetic energy of flowing water into electric energy.

Safety Precautions

- Clean up the work area and wash your hands thoroughly at the end of the activity.

Apparatus

voltmeter

2-hole stopper

Materials

small DC motor from a toy

50 cm bare copper wire

2 L plastic bottle full of water

plastic hose

white glue

wood and plastic material (Popsicle™ sticks and spoons, wooden and plastic)

tub or sink

string

small pulleys

Design Criteria

A. Use the plastic bottle as a reservoir. Design a turbine that will be turned by the water in the bottle.

B. Design the turbine to turn the axle of the toy motor.

C. Attach the toy motor to the voltmeter. You will know your turbine–generator system works if you generate electrical current.

Plan and Construct

1. Draw a detailed plan of your design. Label all the components and describe how each will function.
2. Get your teacher's approval, and then construct and test your generator.
3. Evaluate your generator. Identify and correct any problems you discover.
4. Test the device once again.

Evaluate

1. Do the analysis provided by your teacher.

READING Check

How much energy is lost as electricity moves from generating stations to your home? How is it lost?

Energy from Splitting Atoms

In a thermonuclear generating station, uranium atoms are split by nuclear fission. This splitting releases a tremendous amount of thermal energy. The thermal energy is used to make steam. Steam, under pressure, turns a turbine.

Study Figure 6.9 to see how thermonuclear power is created. Then, review the advantages and disadvantages of nuclear power outlined in Table 6.2.

A Uranium fuel rods are inserted into the reactor core. Nuclear fission begins.

B Fission reactions produce a tremendous amount of thermal energy. This energy is carried away from the reactor by a coolant.

C Coolant is taken to a tank where the thermal energy converts water into steam.

D High-pressure steam flows through pipes and is directed through the blades of a turbine. The blades move and make the shaft spin.

E The spinning turbine turns the generator. The generator converts this mechanical energy into electric energy.

F Transmission lines take electric energy to customers.

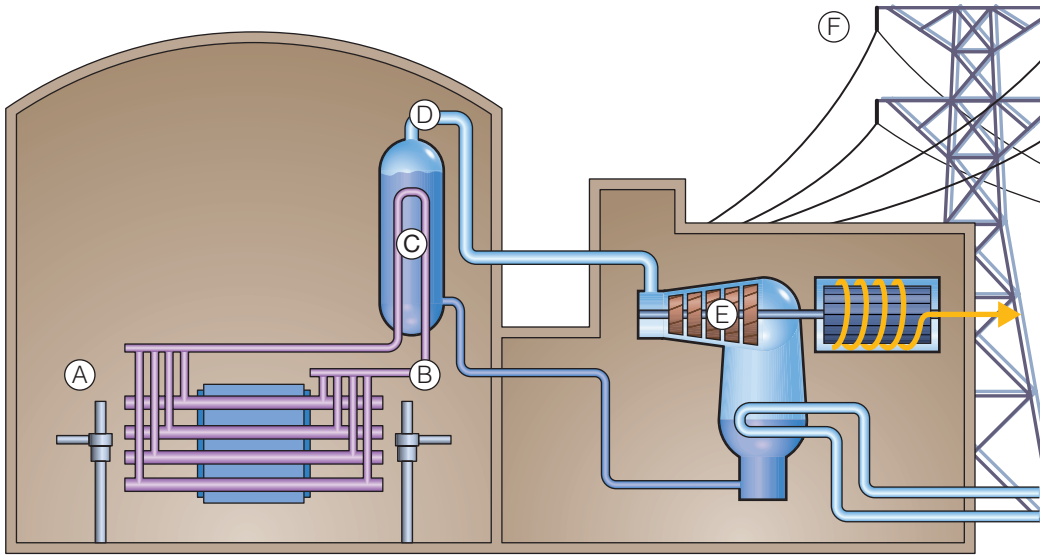


Figure 6.9 This diagram shows how a CANDU nuclear reactor produces electricity from nuclear energy. CANDU reactors were designed and built in Canada. They are used in Canada, Argentina, India, South Korea, Pakistan, and Romania. Two plants are under construction in China.

Try This!

In a group, research and discuss the advantages and disadvantages of using solar, wind, and moving water to produce electricity.

Table 6.2 Advantages and Disadvantages of Using Nuclear Energy

Advantages	Disadvantages
• Reactors do not release harmful gases, such as carbon and sulfur dioxides. • A small quantity of nuclear fuel generates an enormous amount of electricity.	• Nuclear waste is dangerous to life for centuries. • Storing waste safely is expensive and dangerous. • Accidents can release radioactive materials. This material can kill plants and animals. It can also cause illnesses that show up years later.

Distributing Electricity

Electric generating plants are usually located great distances from the communities they serve. Electricity must often be transmitted hundreds of kilometres along power lines. As electricity passes through the lines, about 10 per cent is converted to thermal energy and wasted.

Thermonuclear plants, and thermo-electric plants that burn coal, are often located close to cities. This lessens power loss, but creates environmental concerns.

In Canada, long transmission lines cause other problems. Heavy storms, such as those mentioned in the opening pages of the chapter, knock down power lines. In some cases, the damage can take weeks to repair.

READING Check

List three steps that take place as nuclear energy is converted to electric energy.

DESIGN & DO

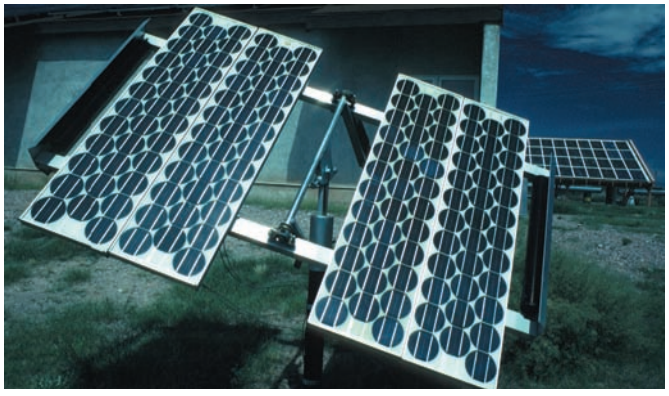
INVESTIGATION 6–C

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Solar Cells

There are other ways to make electricity. One of these is to have **solar cells** convert the Sun's energy into electric energy. This energy can be used immediately or stored in batteries. You can see solar panels powering lawn lights, calculators, electric fences, and the International Space Station.



Solar cells like these convert light energy into electric energy.

Challenge

Design an investigation that will demonstrate the relationship between the intensity of light coming from a source and the amount of electricity produced by a solar cell.

Safety Precautions

- Clean up the work area and wash your hands thoroughly at the end of the activity.

Apparatus

small solar cell
100 W light bulb, with socket and plug
voltmeter
metre stick
marking pen

Materials

50 cm thin wire
tape

Design Criteria

A. Develop a plan that will allow you to test the solar cell with different intensities of light. **Hint:** Either distance or a filter might change the amount of light hitting the solar cell.

B. Include a hypothesis.

C. Describe how you plan to control other variables.

Plan and Construct

1. Gather the apparatus and the equipment required for this investigation.
2. Practise using the solar cell and the voltmeter to make sure you understand how they function.
3. Develop a procedure for your investigation. Get your teacher's approval and then do it.
4. Use a chart to record your observations and data.

Evaluate

1. Do the analysis provided by your teacher.

Check Your Understanding

1. List four steps as the energy in coal is converted to electricity in a thermoelectric generating station.
2. What is a turbine?
3. What does a thermo-electric power plant have in common with a thermonuclear power plant?
4. Why does only 90 percent of the electric energy leaving a power plant reach consumers?

Key Terms

turbine
hydro-electric
thermo-electric
thermonuclear
solar cells

6.3 Electric Energy and Power

Figure 6.10 Electric appliances convert electric energy into other forms of energy. What is the useful energy produced by each of these items?

Energy is the ability to do work. Work is defined as force (F) multiplied by distance (d) over which the force is applied. (Work = F x d).

Force is measured in **newtons**. When a newton of force is applied for one metre of distance (1 N•m), one joule of work is done. Note that the joule is the unit used in measuring work.

Electric energy is able to perform a range of work — from turning the beaters of a mixer, to spinning the blade in a table saw, to moving a freight train.

Power is the rate at which energy is transferred. Power tells how fast energy is used or produced. If a machine uses one **watt** of power, it uses one joule of energy in one second.

Because work and energy are equivalent, power is also the rate at which work is done. Work done quickly means higher power. Work done slowly means lower power.

1 watt = 1 joule per second

or

$1\text{W} = \frac{1\text{ J}}{\text{s}}$

READING Check

What is power?

For example, an electric hair dryer that uses 1500 joules of electric energy every second would be rated at 1500 watts. A light bulb that uses 60 joules of electric energy every second would be rated at 60 watts. The Math Connects that follow will show you how to calculate electric power.

DidYouKnow?

When James Watt developed steam engines, he compared the energy produced by this new technology with something everyone knew in those days. He used the term "horsepower." One horsepower was described as the work done by one horse in one minute.

One horsepower is equal to 746 W. A 9.9 horsepower outboard engine is the equivalent of 746 × 9.9 or 7385.4 W of power. This is about 7.4 kilowatts.

Math CONNECT

Using a Formula to Calculate Power

A generator produces 2 J of electric energy every second. How many watts of power does it produce? Use the equation

$$\text{power} = \frac{\text{energy}}{\text{time}}$$

Steps in Solving It

1. Write down what you know.

power = ?

energy = 2 J

time = 1 s

$$\text{power} = \frac{\text{energy}}{\text{time}}$$

2. *What do you want to find out?*
   How much power is produced.
3. *Use the formula.*
   $\text{power} = \frac{\text{energy}}{\text{time}} = \frac{2\text{ J}}{1\text{ s}}$
   $= 2\text{ J/s}$
4. *Express the power in watts.*
   The generator produces two watts of power.

Solve These

Use Steps 1 to 4 to calculate power for each of these problems.

1. An aquarium light bulb uses 7 J of electric energy in one second. How many watts of power does this light bulb consume in 3 s?
2. Speakers on a computer use 40 J of electric energy in one second. How many watts of power do the speakers consume in 60 s?

What Do You Buy from the "Power" Company?

Although electric utility companies are often called power companies, they really provide electric energy. When you pay an electricity bill, you pay for electric energy.

The consumption of electric energy is measured in watts. Usually, the watts are multiplied by the time it takes to use them. For example, if an appliance uses one watt of power every hour, it uses one **watt hour** (**W•h**) of energy.

$\text{energy} = \text{power} \times \text{time}$

$1\text{ watt hour (W•h)} = 1\text{ watt} \times 1\text{ hour}$

READING Check

What is one watt hour of energy?

Math CONNECT

Watt Hours

How much electric energy does a 1 W light bulb use if it is left on for two hours?

Steps in Solving It

1. *Write down what you know.*
   energy = ?
   power = 1 W
   time = 2 h
   energy = power × time
2. *What do you want to find out?*
   How much energy is used.
3. *Use the formula.*
   energy = power × time
   = 1 W × 2 h
   = 2 W•h
4. *Express the energy in watt hours*
   The light bulb uses two watt hours of energy.

Solve These

Use Steps 1 to 4 to calculate the energy used in each of these problems.

1. How much electric energy does a 100 W light bulb use if it is left on for one hour?
2. How much electric energy does a 240 W fan use if it is left on for two hours?

READING Check

How do watt hours and kilowatt hours compare?

Kilowatt Hours

The watt hour is a small unit of energy. Electric utility companies use a unit of energy 1000 times larger. They bill customers for use of kilowatt hours (kW•h). One **kilowatt hour** (**kW•h**) is equal to 1000 watt hours.

An appliance that uses 1000 watts for one hour, and a small light that uses one watt for 1000 hours, both use 1 kW•h of energy.

Figure 6.11 Electric meters like this measure electric energy in kilowatt hours (kW•h)

Math CONNECT

Calculating Kilowatt Hours

A small kettle is rated at 1000 watts. This means that it uses 1000 watts for each hour it is used. During one week, it is used for two hours. How much energy does it use in kilowatt hours?

Steps in Solving It

1. *Write down what you know.*
   energy = ?
   power = 1000 W
   time = 2 h
   energy = power × time
2. *What do you want to find out?*
   How much energy is used in kW•h.
3. *Use the formula.*
   energy = power × time
   = 1000 W × 2 h
   = 2000 W•h
4. *Divide by 1000 to change W•h to kW•h*

$$\frac{\text{2000 watt hours}}{1000} = 2 \text{ kW•h}$$

5. *Summarize your results.*
   The kettle uses 2 kW•h of energy.

Solve These

Use Steps 1 to 5 to calculate the number of kilowatt hours used by each of the following appliances.

1. How much electric energy does a 1000 W table saw use when run for 3 hours?
2. How much electric energy does a 255 W colour television use if it is on for 4 hours?

Key Terms

newton
power
watt
watt hour
W•h
kilowatt hour
kW•h

Check Your Understanding

1. What units are used to measure the power of electric appliances?
2. How much energy, in kilowatt hours, is used by a 1000 watt hair dyer when it runs for one hour?
3. Why do you think electric power companies measure electric energy in kilowatt hours instead of watt hours?

6.4 Efficiency and Saving Energy

Incandescent light bulbs are designed to convert electric energy into light energy. Incandescent means "glowing with heat." These bulbs produce light when electricity flowing through the filament makes the thin wire white hot. Some of the electric energy is converted to light. A lot of it is converted into other forms of energy.

Complete the Find Out activity to investigate the forms of energy produced by two kinds of light bulbs.

READING Check

What is the major form of waste energy in an incandescent light bulb?

Find Out ACTIVITY

Heat Produced by Two Kinds of Light Bulbs

In this activity, you will investigate thermal energy produced by two kinds of light bulbs.

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Safety Precautions

- Once burned out, compact fluorescents should be placed in the toxic waste disposal.

What You Need

graph paper
ruler
2 retort stands and clamps
2 thermometers
100 watt incandescent light bulb
30 watt compact fluorescent light bulb
2 wired light sockets

A 25 watt compact fluorescent bulb produces the same amount of light as a 100 watt incandescent bulb. The compact fluorescent bulb provides the same amount of light, but uses 75 percent less energy and lasts 10 times longer than an incandescent bulb.

What to Do

1. Develop a chart to record your observations.
2. Put one light bulb in each light socket and attach them to the retort stand.
3. Clamp one thermometer so that its coloured bulb is 1 cm from the top of the incandescent light bulb. Do the same with the second thermometer and the compact fluorescent bulb.
4. Record the temperature shown on each thermometer.
5. Turn on the lights. Record the temperatures every minute for five minutes.
6. Observe the lights from two metres away. Do they give off about the same light intensity?
7. Graph your results. Put time, in minutes, on the horizontal axis (*x*-axis). Put temperature on the vertical axis (*y*-axis).

What Did You Find Out?

1. Do the analysis provided by your teacher.

READING Check

What does the term "efficiency" mean?

Disc CONNECT

To learn more about electrical energy, load the student CD-ROM onto your computer. Launch the **Electrical Energy** applet and follow the instructions.

Efficiency

Efficiency is a measure of how completely input energy is converted to accomplish the desired output energy. Incandescent bulbs and fluorescent bulbs produce about the same amount of light. Incandescent bulbs produce more heat. In this case, thermal energy is not the task. Therefore, incandescent bulbs are less efficient than fluorescent bulbs.

Efficiency can be expressed as a percentage. For example, if a motor is 80 percent efficient, 80 percent of the input energy is converted to do the intended job. Twenty percent of the input energy is wasted.

You can determine the efficiency of an electric device by dividing useful energy output by the total energy input, and then multiplying by 100. Efficiency is always expressed as a percent.

$$\text{Percent efficiency of an electric device} = \frac{\text{useful energy output}}{\text{total electric energy input}} \times 100$$

Math CONNECT

Calculating Efficiency

An electric kettle uses input energy of 240 000 joules to heat water. 196 000 J is actually used to heat the water. Calculate the efficiency of the kettle.

Steps in Solving It

1. *Write down what you know.*
   useful energy output = 196 000 J
   total electric energy input = 240 000 J
   efficiency = ?

   $$\text{Percent efficiency of an electric device} = \frac{\text{useful energy output}}{\text{total electric energy input}} \times 100$$

2. *What do you want to find out?*
   The efficiency of the kettle.
3. *Use the formula.*

   $$\text{Percent efficiency of an electric device} = \frac{\text{useful energy output}}{\text{total electric energy input}} \times 100$$

   $$= \frac{196\ 000\ \text{J}}{240\ 000\ \text{J}} \times 100 = 81.6\%$$

4. *Summarize your results.*
   The kettle is 81.6 percent efficient.

Solve These

1. An incandescent light bulb uses 30 000 J of electric energy. It emits only 900 J of useful energy. What is the efficiency of the light bulb?
2. An electric motor has 100 J of electric energy supplied to it every second. It produces 70 J of kinetic energy every second when it is providing power to a water pump. What is the efficiency of the motor?

It Pays to Be Efficient

Saving energy offers many benefits. If you use less electricity, you will save money on your monthly utility bill.

Using less electricity also benefits the environment. In Alberta, most electricity is generated using fossil fuels; most of that comes from coal-burning power plants. As coal burns, it produces carbon dioxide, sulfur dioxide, and nitrous oxide gases. These waste gases are released into the atmosphere. Carbon dioxide has been linked to global climate change. Sulfur dioxide and nitrous oxides are the primary causes of acid deposition. Using less electricity means that fewer harmful emissions are released into the environment.

READING Check

Why is it important to conserve electric energy?

Figure 6.12 Turning appliances off when they are not being used saves electric energy — and the environment.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect2

To find more ways to conserve electric energy, go to the above web site. Then go to Internet Connects, Unit B, Chapter 6, and then to Conserving Electricity.

DidYouKnow?

It takes approximately 325 kg of coal to generate enough electric energy to keep a 100 watt light bulb on 24 hours a day for 365 days.

Check Your Understanding

1. Why does an incandescent light bulb get so much hotter than a fluorescent light bulb?
2. Use an example to define "efficiency."
3. State three ways to conserve electric energy at home.

Key Terms

efficiency

CHAPTER

6 Review

Key Terms

generator
turbine
hydro-electric
thermo-electric
thermonuclear
solar cells
newton
power
watt
watt hour
W•h
kilowatt hour
kW•h
efficiency

Reviewing Key Terms

If you need to review, the section numbers show where these terms were introduced.

1. In your notebook, match each clue in Column A with a key term in Column B.

A	B
(a) this technology is used to produce electric energy	i. hydro-electric (6.2)
(b) flowing water or steam turns this machine	ii. generator (6.1)
(c) burning coal is used in this type of power plant	iii. thermo-electric (6.2)
(d) a dam and flowing water powers this type of electric-energy plant	iv. solar cells (6.2)
(e) fission of uranium runs this type of power plant	v. power (6.3)
(f) this technology converts light energy into electric energy	vi. turbine (6.2)
(g) the measure of an amount of electric energy used in a period of time	vii. watts (6.3)
(h) the common unit of electric power	viii. efficient (6.4)
(i) what a machine is if most of its input energy is transformed into useful output energy	ix. thermonuclear (6.2)

Understanding Key Ideas

Section numbers are provided if you need to review.

2. Explain how newtons are used.

3. Describe how you can use a coil of wire and a magnet to produce electricity. (6.1)

4. Explain, in point form, how energy in flowing water can be converted into electricity. (6.2)

5. Develop a two-column chart in your notebook. In the first column, list the advantages of generating electric energy using nuclear power. In the second column, list the disadvantages. (6.2)

6. List five things you can do to conserve electric energy. (6.4)

7. Besides keeping your own electric bill low, list two other reasons for reducing your use of electricity. (6.4)

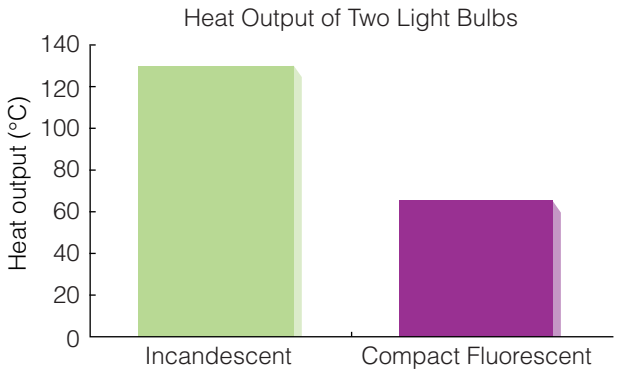
8. Why should you be concerned about the efficiency of the appliances you use? (6.4)

Developing Skills

9. A student conducted an investigation to compare the amount of thermal energy produced by an incandescent light bulb to the amount of thermal energy produced by a compact fluorescent bulb. The results are shown in this graph.

(a) Study the graph. Write a statement that compares the thermal energy released by the two light bulbs.

(b) Write a statement that compares the efficiency of the two light bulbs.



Problem Solving/Applying

10. A clothes dryer uses 3000 watts of electric power. Convert 3000 watts to kilowatts. (6.3)

11. How much electric energy would you use if you left a 100 watt light bulb on for three hours? (6.3)

12. An electric kettle uses 240 000 J of input energy to produce 190 000 J of useful energy. Calculate the percent efficiency of this electric appliance. **Hint:** Use the formula. (6.4)

$$\text{percent efficiency} = \frac{\text{useful output energy}}{\text{input energy}} \times 100$$

13. What does it mean when we say that an electric appliance is 75 percent efficient? (6.4)

14. Use a flowchart to show how the energy in natural gas can be used to generate electric energy. (6.1, 6.2)

Critical Thinking

15. Explain why some people argue that electric energy generated by burning fossil fuels and electric energy generated by using hydroelectric power plants both originated with the Sun. (6.2)

16. Explain the following statement: An electric appliance is never 100 percent efficient. (6.4)

17. Explain how conserving electric energy helps to protect the environment from acid precipitation and global climate change. (6.4)

Pause & Reflect

1. Review your answers to the Getting Ready questions on page 98. If any of your answers need to be corrected or improved, make those changes. If you were unable to answer any of the questions, answer them now.
2. Electricity is an important part of your life. Why is electricity important? Why must all of us conserve as much electricity as possible?